

Supplementary Material

Table S1: Overview of data feedback from responsible authorities and institutions in the federal states of Germany. X= submitted pinpointed data, T= submitted grid-based data, o= referred to data from ornitho.de, *= species that have been excluded from further analysis.

Species	BB	BE	BW	BY	HB	HE	HH	MV	NI	NW	RP	SH	SL	SN	ST	TH
Eurasian Hobby	o	X		X/T	X	X	X			X	o	o	o	X		X
Osprey	X								X			o		X	X	X
Hen Harrier*										X		o				
Western Marsh Harrier	X/o	X		X/T	X/T	X	X			X	o	o	o	X		X
Red Kite	X/o	X	X/T	X/T		X	X		X	X	o	o	o	X	X	X
Lesser Spotted Eagle*																
Black Kite	X/o	X	X	X/T		X	X			X	o	o	o	X		X
White-tailed Eagle	X	X					X		X			X		X	X	X
Golden Eagle*																
Short-eared Owl*				T	X/T	X				X		o				
Eurasian Eagle-Owl	X		T	X/T	X	X	X			X	X	o	o	X	X/T	X
Peregrine Falcon	X	X	T	X/T	X	X	X		X	X	X	o	o	X	X	X
White Stork	X	X	X	T	X	X	X			X	X	X	o	X	X	X
European Honey-Buzzard	X/o	X	X	X/T		X	X			X	o	o	o	X		X
Montagu's Harrier	X		X/T	X		o		X/o	X/T	X	o	o		T	X/T	X

Table S2: Overview of available data per period and Atlas Codes per species after applying a spatio-temporal filter on the presence data from ornitho.de and the federal states.

species	Total N	2018-2023 (%)	2010-2017 (%)	Before 2009 (%)	Atlas Code C (%)	Atlas Code B (%)
Eurasian Hobby	4197	58.78	36.93	4.29	28.14	71.86
Osprey	2222	89.06	10.94	0	72.19	27.81
Western Marsh Harrier	11495	68.82	28.52	2.66	16.05	83.95
Red Kite	27603	75.9	23.52	0.58	41.85	58.15
Black Kite	8982	67.41	31.66	0.92	35.88	64.12
White-tailed Eagle	2665	85.52	13.81	0.68	47.58	52.42
Eurasian Eagle-Owl	4880	68.36	29.88	1.76	62.73	37.27
Peregrine Falcon	3900	80.92	18.77	0.31	52.95	47.05
White Stork	18786	91.64	8.04	0.32	83.04	16.96
European Honey-Buzzard	2918	60.93	35.37	3.7	22.79	77.21

Table S3: Overview of assigned new values (numerical) and original values (factorial) for variables available on a 5km grid for Germany from agraratlas.statistikportal.de.

Variable	original value	new value	comment
Organic farming	no value or to be kept secret		0.0%
	0- <3%		1.5%
	3- <10%		6.5%
	10- <20%		15.0%
	20- <30%		25.0%
	30% plus		40.0% assuming a max. of 50%
Large livestock units	no value or to be kept secret		0
	0- <50		25
	50- <100		75
	100- <150		125
	150- <200		175
	200 plus		250 assuming a max. of 300

Table S4: Overview of all model coefficients of finally selected variables (see file: 'Table_S4.csv')

Text S1: Initial model formulas per species group including all variables an possible quadratic effects and interactions potentially having an impact on occurrences of species within each group.

Wetland species

White-tailed Eagle, Osprey

```

form_wetlands <- occurrence~
  breeding_season_mean_temperature+
  I(breeding_season_mean_temperature^2)+
  breeding_season_precipitation_sum+
  I(breeding_season_precipitation_sum^2)+
  breeding_season_mean_temperature:breeding_season_precipitation_sum+
  CLC_Open_land+
  I(CLC_Open_land^2)+
  Grassland+
  I(Grassland^2)+
  CLC_Open_land:Grassland+
  Road_network+
  I(Road_network^2)+
  Road_network:CLC_Open_land+
  Street_network+
  I(Street_network^2)+
  Street_network:CLC_Open_land+
  Relief_diversity+
  I(Relief_diversity^2)+
  Woody_edge_structures+
  I(Woody_edge_structures^2)+
  CLC_Settlements+
  I(CLC_Settlements^2)+
  CLC_Wetlands+
  I(CLC_Wetlands^2)+
  CLC_Settlements:CLC_Wetlands+
  Grassland:CLC_Wetlands+
  CLC_Open_land:CLC_Wetlands+
  Road_network:CLC_Wetlands+
  Woody_edge_structures:CLC_Wetlands+

```

```

tree_species_diversity+
l(tree_species_diversity^2)+
tree_species_diversity:CLC_Open_land+
Deciduous_trees+
l(Deciduous_trees^2)+
Coniferous_trees+
Road_network:Coniferous_trees+
Street_network:Coniferous_trees+
Relief_diversity:Coniferous_trees+
Woody_edge_structures:Coniferous_trees+
median_day_first_mowing_event+
l(median_day_first_mowing_event^2)

```

Farmland species

Western Marsh Harrier, White Stork, Black Kite, Red Kite

```

form_offen <- occurrence~
breeding_season_mean_temperature+
l(breeding_season_mean_temperature^2)+
breeding_season_precipitation_sum+
l(breeding_season_precipitation_sum^2)+
breeding_season_mean_temperature:breeding_season_precipitation_sum+
Organic_farming+
large_livestock_units+
#l(large_livestock_units)^2+
CLC_Open_land+
l(CLC_Open_land^2)+
CLC_Open_land:large_livestock_units+
CLC_Open_land:Organic_farming+
Grassland+
l(Grassland^2)+
Grassland:CLC_Open_land+
Grassland:Organic_farming+
Grassland:breeding_season_precipitation_sum+
Grassland:large_livestock_units+
Road_network+
l(Road_network^2)+
Road_network:Grassland+
Road_network:CLC_Open_land+
Street_network+
l(Street_network^2)+
Street_network:CLC_Open_land+
Relief_diversity+
l(Relief_diversity^2)+
Relief_diversity:CLC_Open_land+
Relief_diversity:Grassland+
Woody_edge_structures+
l(Woody_edge_structures^2)+
Woody_edge_structures:Grassland+
Woody_edge_structures:CLC_Open_land+
Woody_edge_structures:Road_network+
Woody_edge_structures:Street_network+
Soil_quality_rating+
l(Soil_quality_rating^2)+
Soil_quality_rating:CLC_Open_land+
Soil_quality_rating:Grassland+
Soil_quality_rating:Organic_farming+
Woody_edge_structures:Soil_quality_rating+
Crop_diversity+
Crop_diversity:CLC_Open_land+
Crop_diversity:Soil_quality_rating+
Crop_diversity:Woody_edge_structures+
CLC_Settlements+
l(CLC_Settlements^2)+

```

```

CLC_Settlements:CLC_Open_land+
CLC_Settlements:Grassland+
CLC_Settlements:Crop_diversity+
CLC_Wetlands+
I(CLC_Wetlands^2)+
CLC_Wetlands:CLC_Settlements+
CLC_Wetlands:Road_network+
CLC_Wetlands:Grassland+
CLC_Wetlands:CLC_Open_land+
tree_species_diversity+
I(tree_species_diversity^2)+
tree_species_diversity:CLC_Open_land+
tree_species_diversity:Woody_edge_structures+
Deciduous_trees+
I(Deciduous_trees^2)+
Deciduous_trees:Relief_diversity+
Deciduous_trees:Road_network+
Deciduous_trees:Woody_edge_structures+
Deciduous_trees:Street_network+
Coniferous_trees+
median_day_first_mowing_event+
I(median_day_first_mowing_event^2)+
median_day_first_mowing_event:Grassland+
Relative_crop_edge_density+
#I(Relative_crop_edge_density^2)+
Relative_crop_edge_density:Soil_quality_rating

```

Insectivorous species

Eurasian Hobby, European Honey-Buzzard

```

form_insect <- occurrence~
breeding_season_mean_temperature+
I(breeding_season_mean_temperature^2)+
non_breeding_season_mean_temperature+
I(non_breeding_season_mean_temperature^2)+
breeding_season_mean_temperature:breeding_season_sunshine_duration+
breeding_season_mean_temperature:breeding_season_precipitation_sum+
breeding_season_      +
I(breeding_season_sunshine_duration^2)+
breeding_season_precipitation_sum+
I(breeding_season_precipitation_sum^2)+
non_breeding_season_precipitation_sum+
I(non_breeding_season_precipitation_sum^2)+
Organic_farming+
large_livestock_units+
CLC_Open_land+
I(CLC_Open_land^2)+
CLC_Open_land:large_livestock_units+
CLC_Open_land:Organic_farming+
Grassland+
I(Grassland^2)+
Grassland:CLC_Open_land+
Grassland:Organic_farming+
Grassland:breeding_season_precipitation_sum+
Grassland:large_livestock_units+
Road_network+
I(Road_network^2)+
Road_network:Grassland+
Road_network:CLC_Open_land+
Street_network+
I(Street_network^2)+
Street_network:CLC_Open_land+
Relief_diversity+
I(Relief_diversity^2)+

```

Relief_diversity:CLC_Open_land+
 Relief_diversity:Grassland+
 Relief_diversity:breeding_season_sunshine_duration+
 Woody_edge_structures+
 I(Woody_edge_structures^2)+
 Woody_edge_structures:Grassland+
 Woody_edge_structures:CLC_Open_land+
 Woody_edge_structures:Road_network+
 Woody_edge_structures:Street_network+
 Soil_quality_rating+
 I(Soil_quality_rating^2)+
 Soil_quality_rating:CLC_Open_land+
 Soil_quality_rating:Grassland+
 Soil_quality_rating:Organic_farming+
 Soil_quality_rating:Woody_edge_structures+
 Crop_diversity+
 CLC_Settlements+
 I(CLC_Settlements^2)+
 CLC_Wetlands+
 I(CLC_Wetlands^2)+
 CLC_Wetlands:Grassland+
 CLC_Wetlands:CLC_Open_land+
 CLC_Wetlands:Woody_edge_structures+
 tree_species_diversity+
 I(tree_species_diversity^2)+
 tree_species_diversity:CLC_Open_land+
 tree_species_diversity:Woody_edge_structures+
 Coniferous_trees+
 Deciduous_trees+
 I(Deciduous_trees^2)+
 Relief_diversity:Deciduous_trees+
 Street_network:Deciduous_trees+
 Road_network:Deciduous_trees+
 Woody_edge_structures:Deciduous_trees+
 Woody_edge_structures:Coniferous_trees+
 median_day_first_mowing_event+
 I(median_day_first_mowing_event^2)+
 median_day_first_mowing_event:Grassland+
 Relative_crop_edge_density+
 I(Relative_crop_edge_density^2)+
 Relative_crop_edge_density:Soil_quality_rating

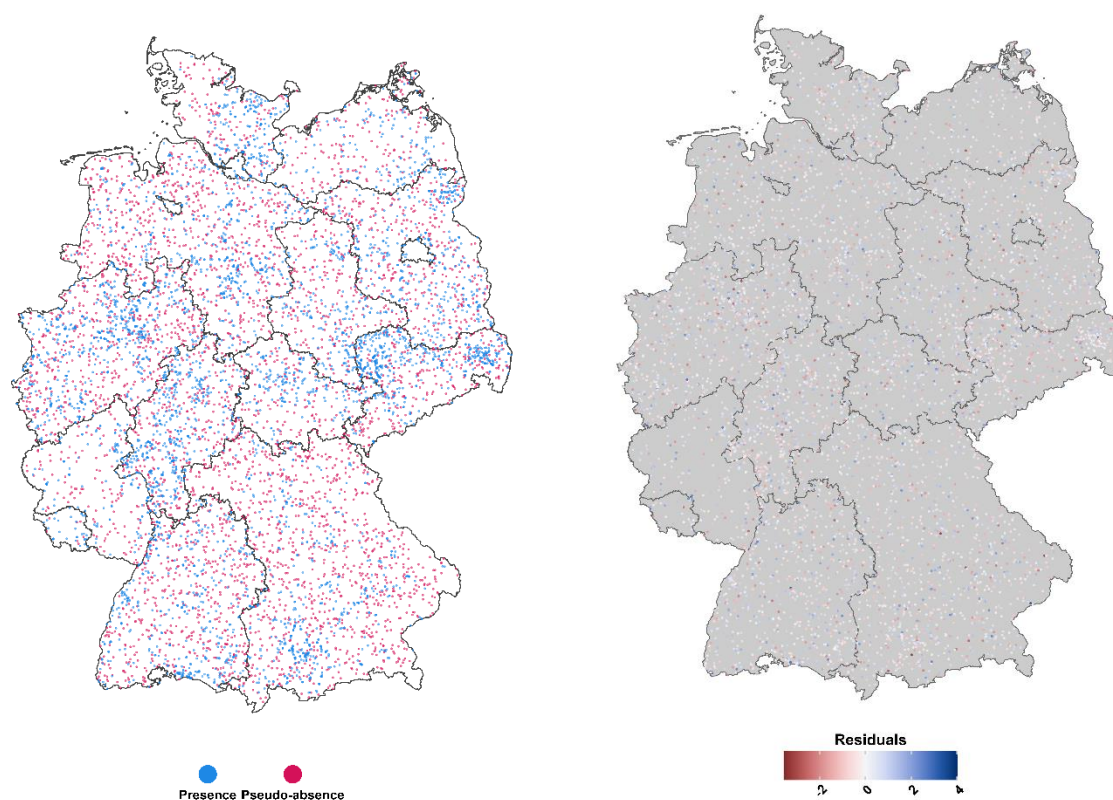
Relief and settlement species
 ## Eurasian Eagle-Owl, Peregrine Falcon

form_other <- occurrence~
 breeding_season_mean_temperature+
 I(breeding_season_mean_temperature^2)+
 breeding_season_precipitation_sum+
 I(breeding_season_precipitation_sum^2)+
 breeding_season_mean_temperature:breeding_season_precipitation_sum+
 Organic_farming+
 CLC_Open_land+
 I(CLC_Open_land^2)+
 Grassland+
 I(Grassland^2)+
 Grassland:CLC_Open_land+
 Grassland:CLC_Settlements+
 Road_network+
 I(Road_network^2)+
 Road_network:CLC_Open_land+
 Street_network+
 I(Street_network^2)+
 Street_network:CLC_Open_land+

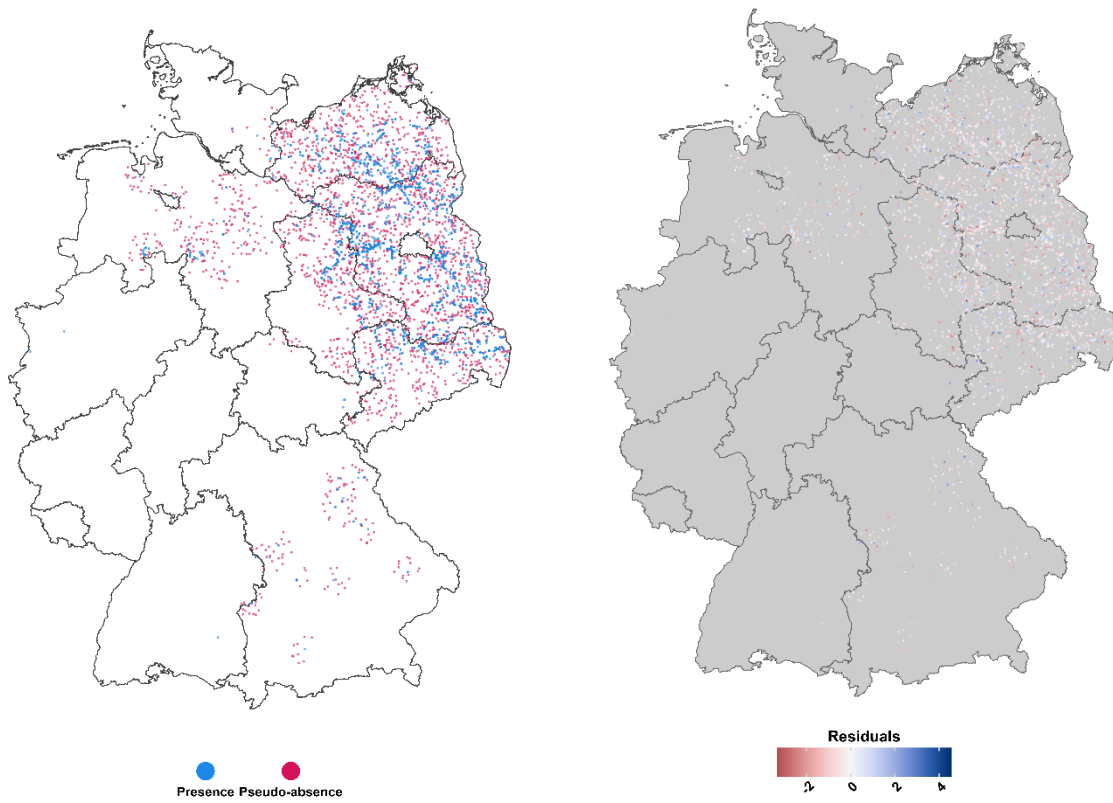
Relief_diversity+
 I(Relief_diversity^2)+
 Soil_quality_rating+
 I(Soil_quality_rating^2)+
 Crop_diversity+
 CLC_Settlements+
 I(CLC_Settlements^2)+
 CLC_Settlements:CLC_Open_land+
 CLC_Settlements:Grassland+
 CLC_Settlements:Crop_diversity+
 CLC_Settlements:Street_network+
 tree_species_diversity+
 I(tree_species_diversity^2)+
 tree_species_diversity:CLC_Open_land+
 Deciduous_trees+
 I(Deciduous_trees^2)+
 Coniferous_trees+
 Relief_diversity:Coniferous_trees+
 Coniferous_trees:Road_network+
 Coniferous_trees:Street_network+
 Coniferous_trees:Woody_edge_structures+
 Woody_edge_structures+
 I(Woody_edge_structures^2)+
 Woody_edge_structures:CLC_Open_land+
 median_day_first_mowing_event+
 I(median_day_first_mowing_event^2)

Figure S1: Locations of presence and pseudo-absence data (left) and residuals of model predictions (right) per species.

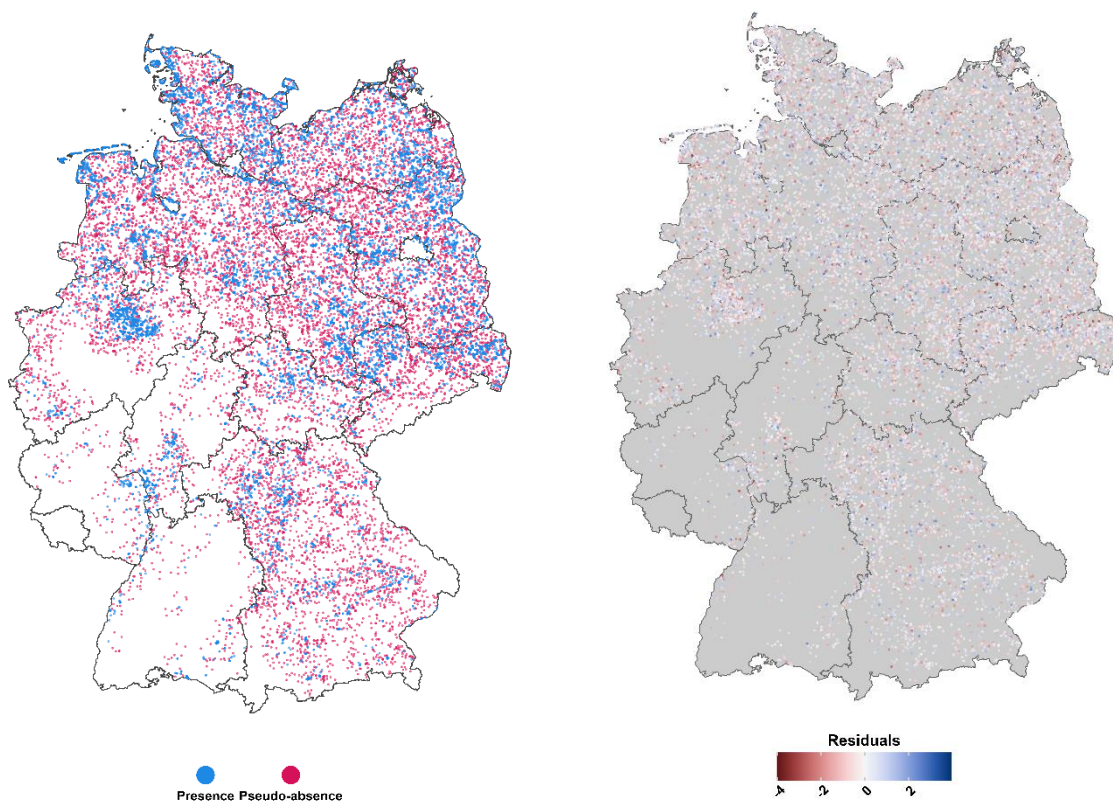
Eurasian Hobby



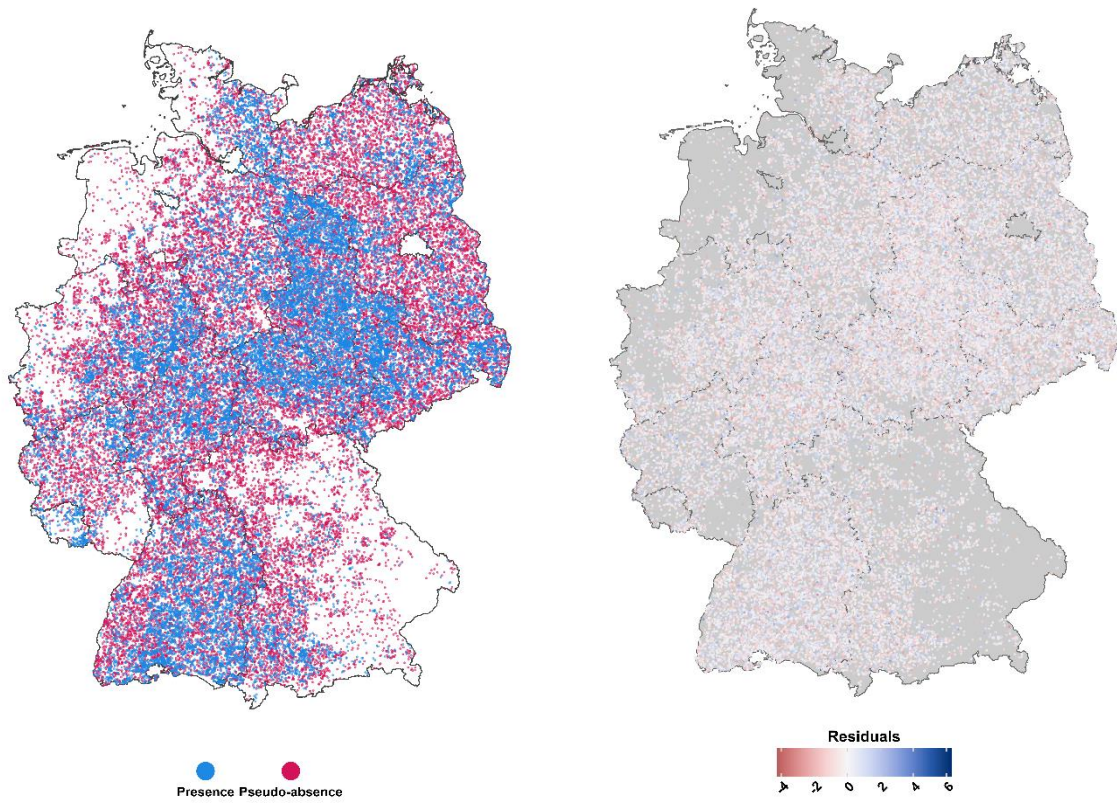
Osprey



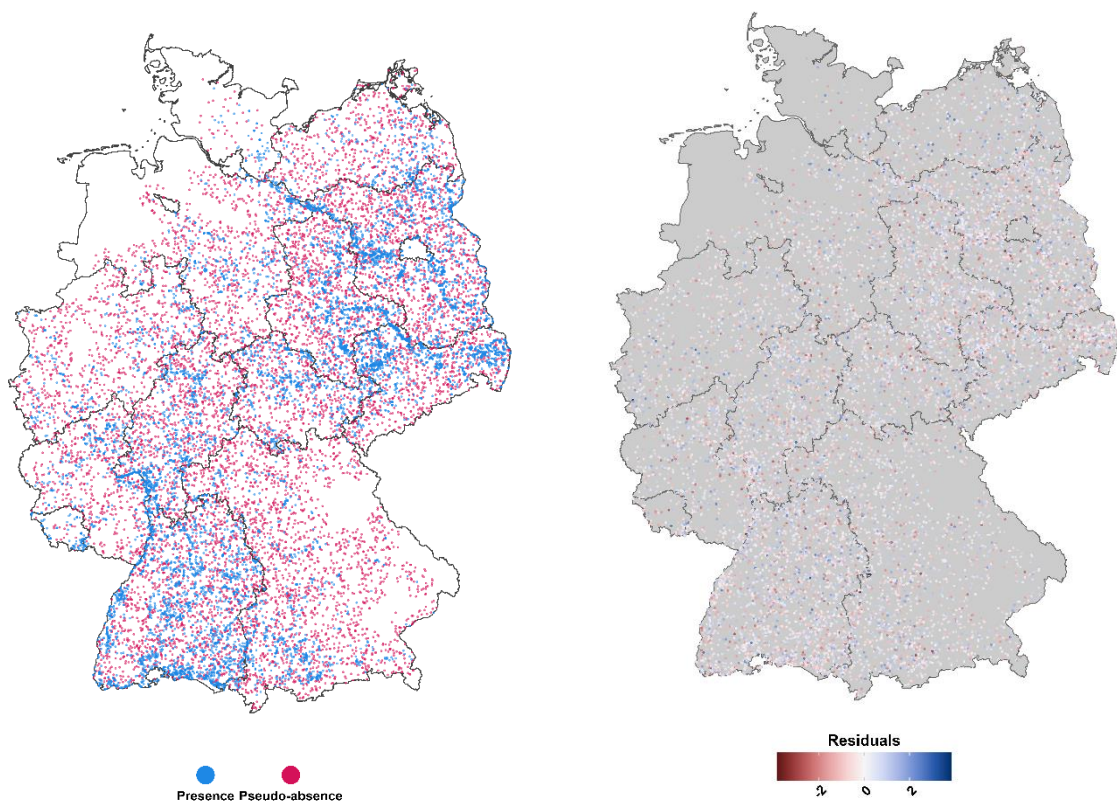
Marsh Harrier



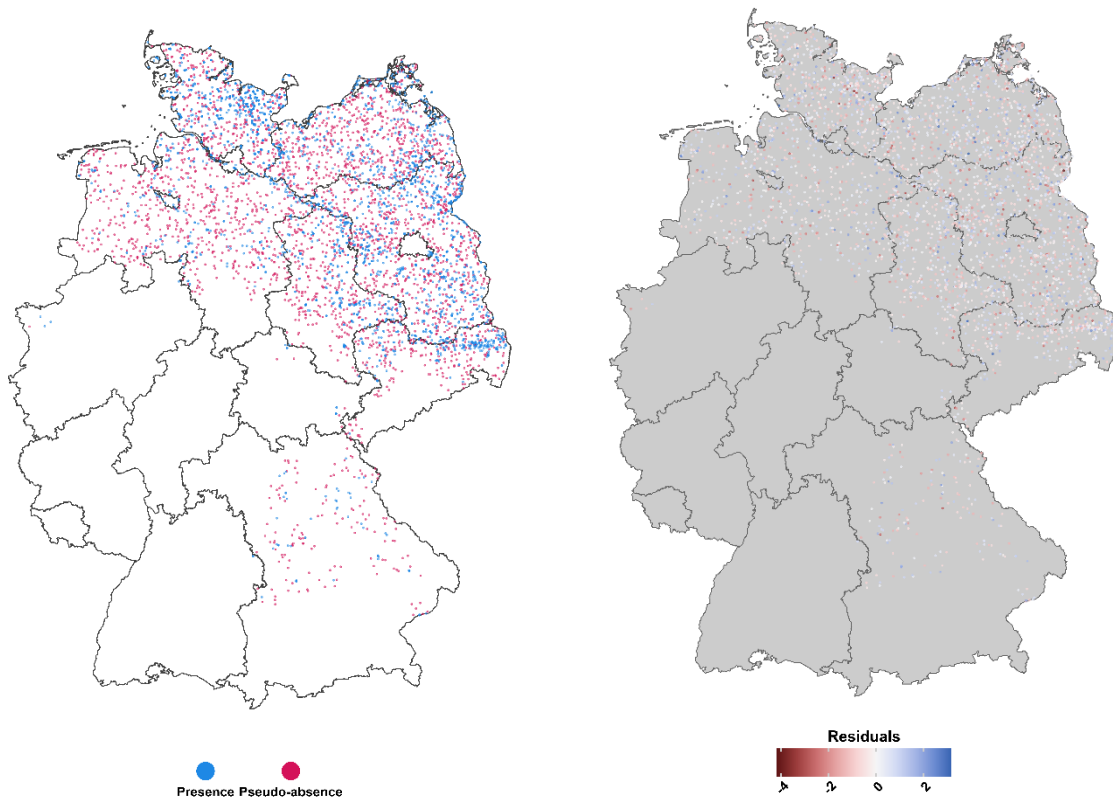
Red Kite



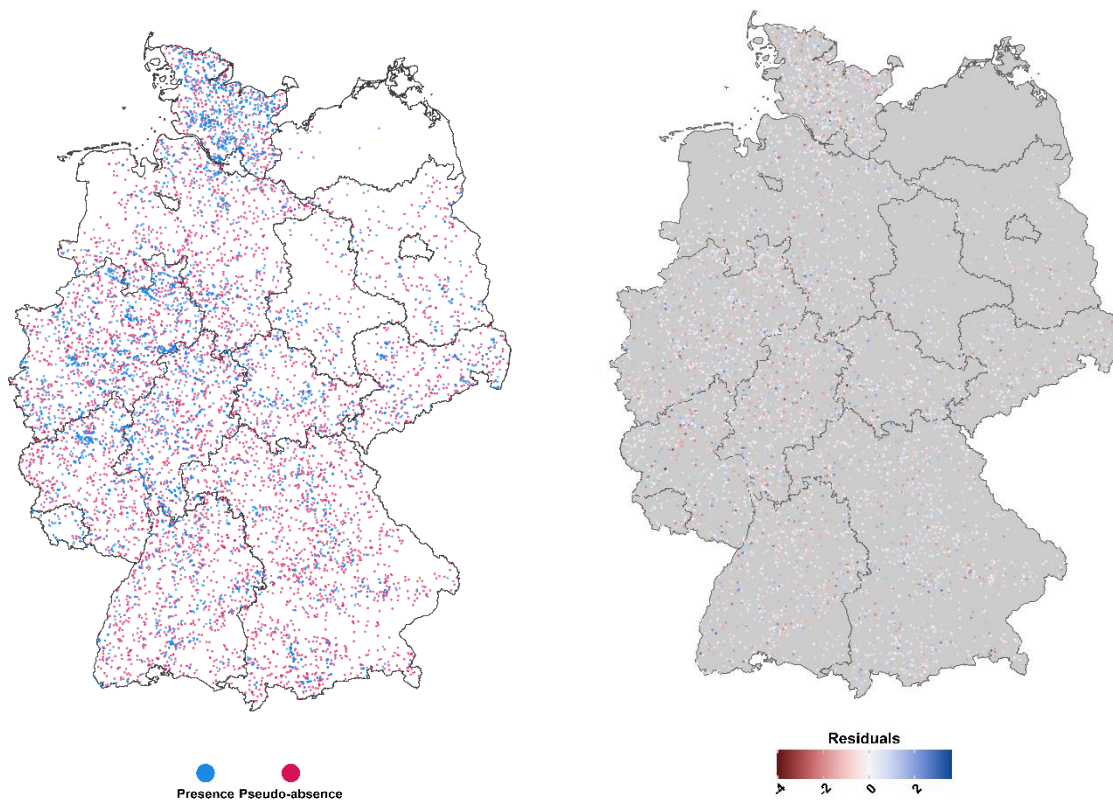
Black Kite



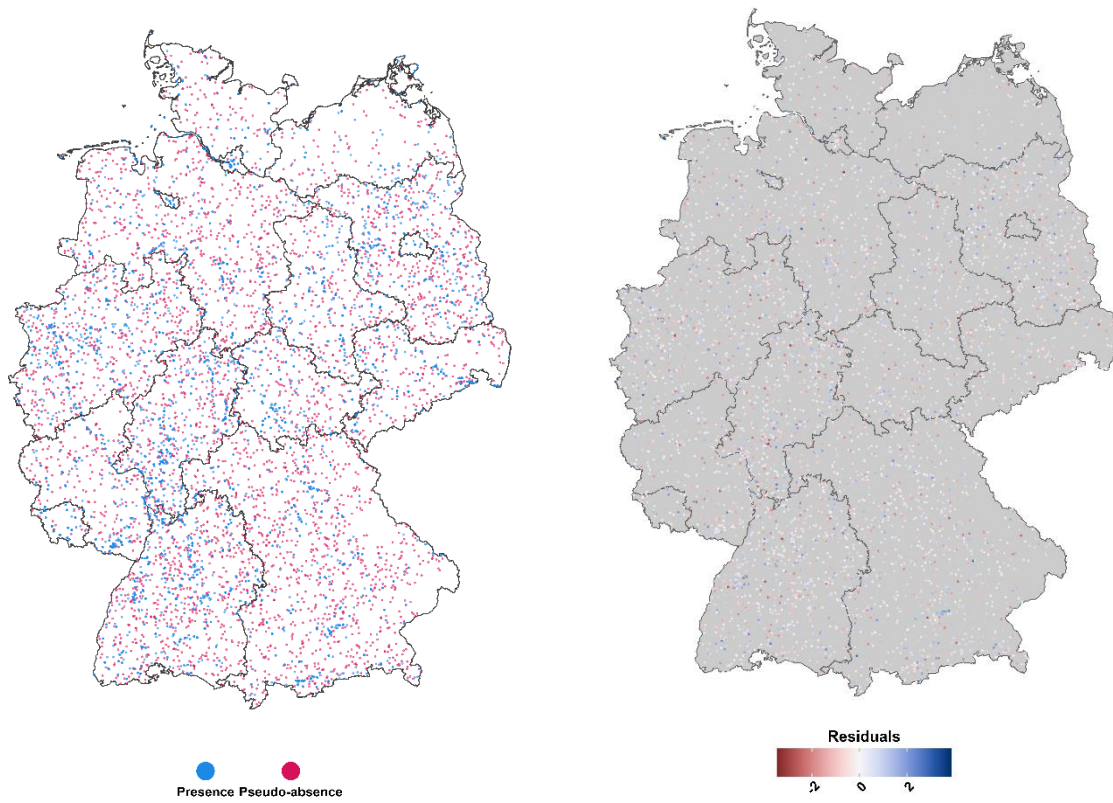
White-tailed Eagle



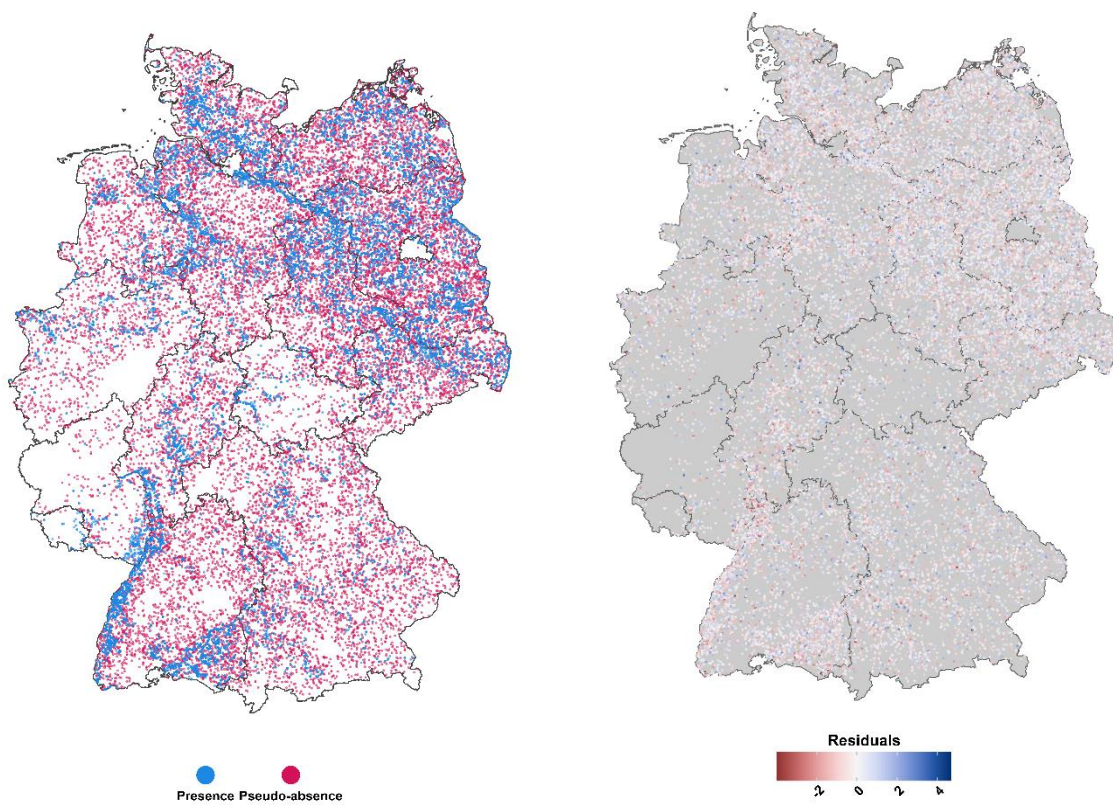
Eagle-owl



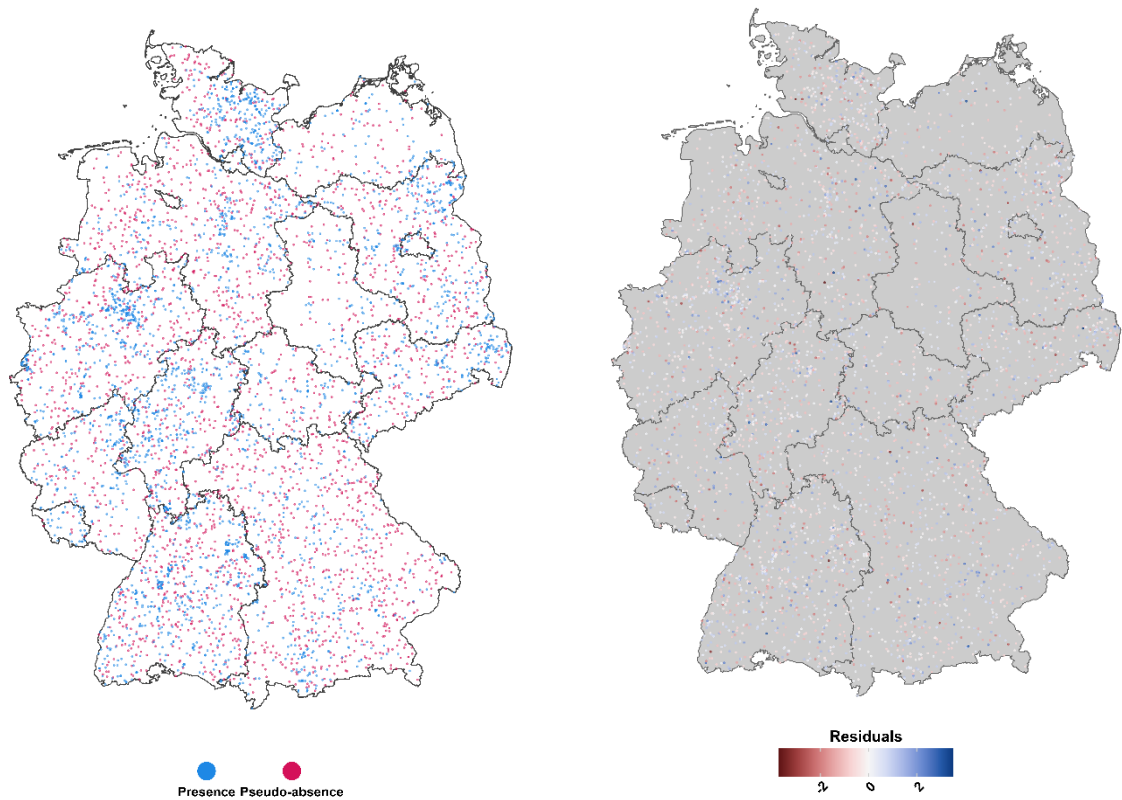
Peregrine Falcon



White Stork



European Honey-Buzzard



Montagu's Harrier

